UL 1411

STANDARD FOR SAFETY

Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances

UL Standard for Safety for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411

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Summary of Topics

This Seventh Edition of the Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411, is being issued as an Editorial New Edition update only. No changes to the requirements have been made.

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Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances

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The most recent designation of ANSI/UL 1411 as a Reaffirmed American National Standard (ANS) occurred on August 31, 2015. ANSI approval for a standard does not include the Cover Page, Transmittal Pages and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at http://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements apply to transformers, autotransformers, and motor-transformers intended to be used in audio-, radio-, and television-type appliances in which the primary winding is connected across the supply circuit.

1.2 The requirements in Sections 6 – 17, 25 – 28, 30, and 31 also apply to transformers intended for use in high-frequency, switching-type power supplies in which the transformer provides isolation from the supply circuit.

1.3 These requirements do not apply to transformers that are intended to transform only audio, video, and other signal waveforms. Those transformers are covered by the Standard for Isolating Signal and Feedback Transformers for Use in Electronic Equipment, UL 1876.

1.4 These requirements apply to a transformer or motor transformer that includes a separate current-limiting impedance such as a positive temperature coefficient (PTC) device complying with the requirements for thermistor-type devices, or a resistor complying with the Standard for Fusing Resistors and Temperature-Limited Resistors for Radio- and Television-Type Appliances, UL 1412.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

2.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

2.3 A component shall be used in accordance with its rating established for the intended conditions of use.

2.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

3 Units of Measurement

3.1 When a value for measurement is followed by a valued in other units in parentheses, the first stated valued is the requirement.

4 Undated References

4.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

5 Glossary

5.1 For the purpose of this standard the following definitions apply.

5.2 ENCAPSULATION COMPOUND – A material, generally of the polymeric type, that is at least 1/32 inch (0.8 mm) thick (when solidified) and that covers the transformer windings.

5.3 HOUSING – A partial or complete enclosure, generally of polymeric material or metal, that is around the outside of all or part of the transformer (such as end bells) but is not in contact with current-carrying parts.

5.4 IMPREGNATION COMPOUND – A coating material less than 1/32 inch (0.8 mm) thick, generally of the polymeric type and commonly in the form of varnish, that is absorbed by insulating materials such as electrical grade paper.

5.5 LAYER-WOUND TRANSFORMER – A transformer in which all of the turns in each layer of each winding are in a single plane. Turns in each layer are wound tightly next to each other with no gaps between them and the turns do not cross over other turns in that layer or the adjacent layers.

5.6 POTTING COMPOUND – A material intended to fill all the air spaces inside the housing of a transformer.

5.7 TRANSFORMER – A collective term used to designate a transformer, a motor transformer, or an autotransformer.

5.8 WINDING – A coil of wire including the start, finish, and crossover leads up to the point where insulated leads or terminals are connected.

CONSTRUCTION

6 Enclosure

6.1 A material used as all or part of the enclosure (end bells) of a transformer shall be classified V-0 or less flammable in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: This requirement does not apply to a bushing through which a lead passes.

6.2 A complete, individual enclosure (end bells) is not required when:

a) Live parts are not accessible; or

b) The transformer is used in an appliance having an enclosure that renders the live parts inaccessible.

An individual enclosure may be required in the end product if the transformer has not been tested as described in Abnormal Operation Tests, Section 29.

6.3 A potting compound employed in a transformer shall be classified HB or less flammable in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. A potting compound classified HB or less flammable using 1/16-inch (1.6-mm) thick flat-stock samples may be used in lesser thicknesses in the transformer when determined acceptable.

6.4 An encapsulation compound that covers the exterior surface of a transformer shall be classified HB or less flammable in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. An encapsulation compound classified HB or less flammable using 1/16-inch (1.6-mm) thick flat-stock samples may be used in lesser thicknesses in the transformer when determined acceptable.

7 Leads

7.1 Insulation

7.1.1 The insulation on lead wires shall be rated for the voltage involved and the highest temperature reached under any condition of actual use, and shall be rated ″VW-1.″

7.2 Cords

7.2.1 A flexible cord of a transformer shall comply with the requirements in the standard for the end-use product in which the transformer is intended to be used and shall be rated ″VW-1.″

7.2.2 A power-supply cord or wiring harness shall be provided with a polarized (two-blade polarized or three-wire grounding) type attachment plug that conforms with one of the configurations covered in the Standard for Wiring Devices – Dimensional Requirements, NEMA WD-6, and in the Standard for Attachment Plugs and Receptacles, UL 498. The attachment plug shall comply with the requirements in the Standard for Cord Sets and Power-Supply Cords, UL 817.

Exception: When the product is intended to be connected to supply circuits not defined in the National Electrical Code, ANSI/NFPA 70, or for connection to supply-circuit receptacles that are not defined in the Standard for Wiring Devices – Dimensional Requirements, NEMA WD-6, the configuration of the attachment plug is to conform to the applicable Standards of the country into which the product is intended to be shipped. This exception applies only when the product is set for use on the foreign supply circuit when leaving the factory.

7.2.3 The conductors of a parallel flexible cord of a transformer shall not be split external to the transformer enclosure (end-bells).

7.3 Sleeving, tape, and tubing

7.3.1 Sleeving and tubing used on lead wires shall be rated ″VW-1.″ Tape used on lead wires shall be flame-retardant.

7.4 Connections between leads

7.4.1 The connection between a lead, including a flexible cord, and a winding or other part of the transformer shall be soldered, welded, or otherwise securely connected. A solder joint shall be mechanically secure before soldering.

7.4.2 When a lead is rigidly held in place without the use of solder, or when it is retained in place by an acceptable means so as not to be subjected to any motion, additional mechanical security is not required. Mechanical securement of a lead is not required when separation of the connection does not result in a risk of fire or electric shock.

7.5 Strain relief

7.5.1 Strain relief shall be provided so that stress on each individual lead, including a flexible cord, is not transmitted to the connection inside the transformer. See 27.1.

7.5.2 A strain-relief means shall not depend solely on adhesion between the lead and a potting compound, unless an investigation shows it to be acceptable.

7.6 Openings for wires

7.6.1 An edge of an opening for a cord or wire connected in the primary circuit shall be free of burrs and fins that may damage the conductor insulation. Unless a bushing is provided, the edges of an opening in a sheet-metal enclosure shall be rolled or formed.

7.7 Bushings

7.7.1 A bushing shall be secured in place.

8 Interconnection of Windings

8.1 A discrete component that provides a conductive connection between the primary and secondary winding of a transformer shall have a resistance that limits the leakage current in the end use to an acceptable value that does not exceed 12-megohms. The wattage rating of the component shall be at least 1/2 watt.

8.2 The resistance mentioned in 8.1 shall not be exceeded considering the maximum tolerance of the resistor used. For example, a resistor rated 10 megohms with a 20-percent tolerance is acceptable for the 12-megohms maximum resistance application.

8.3 A capacitor with or without a built-in shunt resistor shall comply with the requirements in the Standard for Fixed Capacitors for Use in Electric Equipment – Part 14: Sectional Specifications: Fixed Capacitors for Electromagnet Interference Suppression and Connection to the Supply Mains, UL 60384-14.

9 Protective Devices

9.1 A protective device installed as part of a transformer shall comply with the requirements for the construction, performance, and use for such a device.

9.2 Protective devices covered by 9.1 include fuses, overtemperature and overcurrent protectors, eutectic materials, and similar devices intended to interrupt the flow of current as a result of transformer overload.

10 Separate Current-Limiting Material

10.1 Separate current-limiting impedances such as a positive temperature coefficient (PTC) device complying with the requirements for the thermistor type devices, or a resistor complying with the Standard for Fusing Resistors and Temperature-Limited Resistors for Radio- and Television-Type Appliances, UL 1412, may be provided.

11 Live Part Insulating Material

11.1 Insulating material for the support of terminals operating at 42.4 volts peak or more or having available power of more than 15 watts shall be:

a) Of acceptable mechanical strength for the application;

b) Classified V-2 or less flammable in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. Material classified V-2 or less flammable using 1/16-inch (1.6-mm) thick bar specimens may be accepted in lesser thicknesses in a transformer;

c) Rated for the temperature involved in the end-use appliances as described in 21.1; and

d) Suitable for the sole support of live parts as determined by investigation regarding factors as hot-wire ignition, high-current-arc ignition, volume resistivity, and dielectric strength.

Exception No. 1: Volume resistivity and dielectric strength sole support requirements do not apply to a polymeric material subjected to:

a) An additional dielectric voltage-withstand test conducted between adjacent supply circuit terminals on the transformer (with leads disconnected) following the method and complying with the requirements described in the Dielectric Voltage-Withstand Test, Section 25, and

b) Insulation resistance testing between adjacent supply circuit terminals (with leads disconnected) in addition to the locations described in the Insulation Resistance Test, Section 28. The minimum acceptable resistance between these terminals is 10 megohms.

Exception No. 2: A polymeric material used to support pin-type transformer terminals that are specifically intended for mounting through holes in a printed wiring board need not be evaluated for the sole support of live parts.

Exception No. 3: The requirements in 11.1 (a) – (c) do not apply to materials used to secure leads in position.

12 Bobbin Material

12.1 Insulating material used for bobbins shall comply with the requirements specified in 11.1 (a) – (c).

Exception: Bobbin materials may be rated HB or less flammable if the transformer is encapsulated by a material rated V-0 or better.

13 Coil Insulation

13.1 A coil shall be constructed to provide insulation between:

a) Uninsulated primary wires of opposite polarity as specified in 13.7;

b) The primary winding and the secondary windings (or shield) as specified in 13.7;

c) The primary winding and the core as specified in 13.8;

d) The primary winding lead connections and the shield or transformer enclosure (end bells), when provided, as specified in 13.9;

e) The primary input lead connections and the adjacent winding (or shield) as specified in 13.12; and

f) The secondary output lead connections and the primary winding as specified in 13.13.

13.2 The term coil also includes start, finish, and crossover leads, up to the point where insulated leads are provided.

13.3 Coil insulation shall:

a) Be treated to render it resistant to moisture unless inherently moisture resistant. Reference the Insulation Resistance Test, Section 28.

Exception: Film-coated magnet wire is not required to be additionally treated to prevent moisture absorption.

b) Be of equivalent mechanical strength when compared to electrical grade paper of the thickness required by 13.6 – 14.1. Consideration is to be given to cold flow due to pressure on the insulation and the presence of sharp edges and splices.

c) Have equivalent dielectric voltage-withstand strength when compared to electrical grade paper of the thickness required by 13.6 – 14.1. See 25.2.1.

d) Be acceptable for the temperature involved in the end-use appliance. See 21.1.

13.4 Generic materials that have been found to be equivalent to electrical grade paper, as specified in 13.3 (b) and (c), are specified in Equivalent Generic Materials, Section 15.

13.5 The thickness of insulating tape is to be measured with the adhesive in place.

13.6 Electrical grade paper having a total thickness not less than 0.012 inch (0.30 mm) or the equivalent of such insulation shall be used between:

a) Uninsulated, primary wires of opposite polarity;

b) Multiple primary windings;

c) The body of a primary-connected thermal protector and the adjacent windings; and

d) The body of a secondary-connected thermal protector located adjacent to a primary winding.

See 13.3 (b), (c), and (d), and 13.4.

Exception No. 1: This requirement does not apply when the spacing specified in 16.1 is provided.

Exception No. 2: The requirements in (a) and (b) do not apply to switch mode transformers if the risk of fire and shock is evaluated by a short-circuit test of the transformer windings in the end-use product.

13.7 Insulation between the primary and the secondary windings (or shield) shall be one of the following:

a) Electrical grade paper having a total thickness not less than 0.012 inch (0.30 mm);

b) A polymeric coil form not less than 0.025 inch (0.64 mm) thick; or

c) The equivalent of the insulation specified in (a) or (b). See 13.3 (b), (c), and (d) and 13.4.

13.8 Insulation between the primary winding and the core shall be one of the following:

a) Electrical grade paper having a total thickness not less than 0.012 inch (0.30 mm);

b) A polymeric coil form not less than 0.025 inch (0.64 mm) thick; or

c) The equivalent of the insulation specified in (a) or (b). See 13.3 (b), (c), and (d) and 13.4.

13.9 Insulation between the primary winding lead connections and the shield or the transformer enclosure (end bells) shall be one of the following:

a) Electrical grade paper having a total thickness not less than 0.012 inch (0.30 mm) if used in conjunction with an air spacing of one-half that specified in 16.1;

b) Electrical grade paper having a total thickness not less than 0.023 inch (0.58 mm) if the insulation is in contact with the end bell; or

c) The equivalent of the insulation specified in (a) or (b). See 13.3 (b), (c), and (d) and 13.4.

Exception: This requirement does not apply when the spacing specified in 16.1 is provided.

13.10 Insulation between the crossover leads and the adjacent winding, transformer enclosure (end bells), or core shall be one of the following:

a) Electrical grade paper, having a total thickness of not less than 0.012 inch (0.30 mm);

b) Electrical grade paper having one-half the thickness specified in (a) if used in conjunction with an air spacing of one-half that specified in 16.1; or

c) The equivalent of the insulation specified in (a) or (b). See 13.3 (b), (c), and (d) and 13.4.

Exception No. 1: This requirement does not apply when the spacing specified in 16.1 is provided.

Exception No. 2: This requirement does not apply to insulation between secondary crossover leads and:

a) The secondary winding;

b) The transformer enclosure (end bells); or

c) The core.

Exception No. 3: The type and thickness of the insulation between a crossover lead and the winding to which it is connected may differ from that specified in Exceptions No. 1 and 2 or may be a through-air spacing if:

a) The coil withstands the Dielectric Voltage-Withstand Test described in 25.1.1 – 25.1.4 with the potential applied between the coil leads, with the inner coil lead cut at the point where it enters the layer; or

b) The coil withstands the induced potential test described in 25.3.1 and 25.3.2.

13.11 In accordance with Exception No. 3 to 13.10, a crossover lead that passes through a slot in a molded bobbin is considered to have acceptable insulation and spacing when:

a) The slot provides a graduated through-air spacing to the winding, increasing to the end turns; and

b) The crossover leads and winding withstand the induced-potential test described in 25.3.1 and 25.3.2.

13.12 Electrical grade paper having a total thickness not less than 0.023 inch (0.58 mm) or equivalent insulation (see 13.3 (b), (c), and (d) and 13.4) shall be used as insulation between:

a) The primary input lead connections and the adjacent winding (or shield); and

b) The secondary output lead connections and the primary winding.

13.13 The insulation between splices, winding to protector connections, and similar items shall comply with 13.12.

13.14 The requirements in 13.6 – 13.13 are not applicable to insulation in the thin sheet material irrespective of its thickness when used in high-frequency type transformers, if:

a) The transformer insulation is used within the equipment protective enclosure and is not subject to handling or abrasion during operator servicing; and

b) One of the following applies:

1) Insulation comprises three layers of material for which all combinations of two layers together comply with the dielectric voltage-withstand test described in 25.1.1 – 25.1.6.

2) Insulation comprises at least two layers of material, each of which complies with the dielectric voltage-withstand test described in 25.1.1 – 25.1.6.

13.15 The enamel or other insulating coating on winding wire that is normally used in transformer construction is not considered to be insulation in thin sheet material.

14 Outer-Wrap and Crossover-Lead Insulation

14.1 Insulating material – outer-wrap and crossover-lead insulation – used to render live parts inaccessible shall not be less than 0.028 inch (0.71 mm) thick.

Exception: The insulation need not be provided when the transformer is used in an appliance with an enclosure that renders live parts inaccessible.

15 Equivalent Generic Materials

15.1 The insulation between the transformer parts specified in Coil Insulation, Section 13, and Outer-Wrap and Crossover-Lead Insulation, Section 14, may be of the generic material types specified in Table 15.1 when the layer or layers of each generic material are of a minimum thickness so that all layers collectively are greater than or equal to the minimum thickness required (T):

$$T \leq A_1(EF_1) + A_2(EF_2) + A_3(EF_a)$$

in which:

T is:

a) The constant 0.012 inch (0.30 mm) for insulation between points identified in 13.6 – 13.8, 13.9(a), and 13.10(a); and

b) The constant 0.023 inch (0.58 mm) for insulation between points identified in 13.9(b) and 13.12.

A_1, A_2, A_3 is the total thickness of each generic material type, inches (mm); and

EF_1, EF_2, EF_3 is the equivalency factor specified in Table 15.1 for the generic material type corresponding to A_1, A_2, A_3.

Table 15.1
Equivalency factors for insulation materials

Generic material	Equivalency factor (EF)
Acetate sheet	1.5
Aramid paper	2
Electrical grade paper, fiber, or pressboard	1
Fluorinated ethylene propylene (FEP)	3
Impregnated cotton cloth	1
Impregnated glass or acetate cloth	1.2
Impregnated rag paper	1.3
Polyester	2
Polyethylene terephthalate	2
Polyimide (PI)[a]	6
Polytetrafluoro-ethylene (PTFE) (teflon)	3
Polyvinyl chloride (PVC) tape and tubing	1.3
Silicone rubber (SIR)	0.5
Varnished cambric (cloth)	1.6

NOTE – See 15.1.
[a] Additional material required over connections for mechanical strength.

16 Spacings

16.1 Spacings shall not be less than the applicable values specified in Table 16.1:

a) Between uninsulated live primary parts of different potential, including film-coated magnet wire;

b) Between any uninsulated live primary part and:

1) Any dead metal part, including the core; and

2) Any uninsulated secondary part.

Exception: This requirement does not apply to a transformer intended for use in an appliance where the transformer core and secondary windings will be electrically isolated from all accessible metal parts.

Table 16.1
Minimum spacings

Potential involved, volts (rms)	Through air		Over surface			
			Protected against deposition of dirt		Not protected against deposition of dirt	
	inch	(mm)	inch	(mm)	inch	(mm)
0 – 50	1/16	(1.6)	1/16	(1.6)	1/16	(1.6)
51 – 150	1/16	(1.6)	1/16	(1.6)	1/8	(3.2)
151 – 250	1/8	(3.2)	1/8	(3.2)	1/4	(6.4)
NOTE – The spacings apply to coils, crossover leads, splices, uninsulated lead wires, and any turn of the primary winding to any turn of the secondary winding. The spacings do not apply to turn-to-turn spacings of a coil.						

16.2 The insulation between the primary and secondary windings in a flanged bobbin-wound transformer having the primary winding wound over the secondary winding, or vice versa, shall be as follows (or an equivalent construction):

a) Formed, molded, or extruded material having continuous bent-up edges tightly fitted against the outside bobbin end-flanges. The height of the bent-up edges shall not be less than 1/32 inch (0.8 mm) higher than the top layer of the outer winding. See Figure 16.1.

b) Formed, molded, or extruded material having continuous bent-up edges with the gap between this insulation and the outside bobbin end-flanges covered with a material that complies with Coil Insulation, Section 13, and overlaps the insulating material and the bobbin end-flanges by minimum 1/8 inch (3.2 mm). See Figure 16.2.

c) Insulation that extends from end-flange to end-flange of the bobbin, and the sides of the secondary winding are offset a minimum of 1/8 inch (3.2 mm) from the sides of the primary winding by a spacer or a built-in step in the bobbin end-flange. See Figure 16.3.

Exception No. 1: For a layer-wound transformer, the spacer may be reduced to a minimum width of 1/16 inch (1.6 mm).

Exception No. 2: For a layer wound transformer where a spacer is not provided, an additional positive means shall be provided to maintain the minimum required spacing of 1/16 inch (1.6 mm).

d) Winding insulation that extends from end-flange to end-flange of the bobbin and is overlapped by a tape that:

1) Extends up and over the top edge of the bobbin end-flange;

2) Overlaps the winding insulation and bobbin end-flange by at least 1/8 inch (3.2 mm); and

3) Complies with Coil Insulation, Section 13. See Figure 16.4.

e) Insulation that extends from end-flange to end-flange of the bobbin, and the sides of both the primary and secondary winding are set in 1/16 inch (1.6 mm) from the bobbin end-flange by a spacer or a built-in step in the bobbin end-flange. See Figure 16.5.

Exception No. 1: For a layer-wound transformer, the spacer may be reduced to a minimum width of 1/32 inch (0.8 mm).

Exception No. 2: For a layer wound transformer, where a spacer is not provided, an additional positive means shall be provided to maintain the minimum required spacing of 1/32 inch (0.8 mm).

Figure 16.1
Bobbin wound transformer with inner bobbin

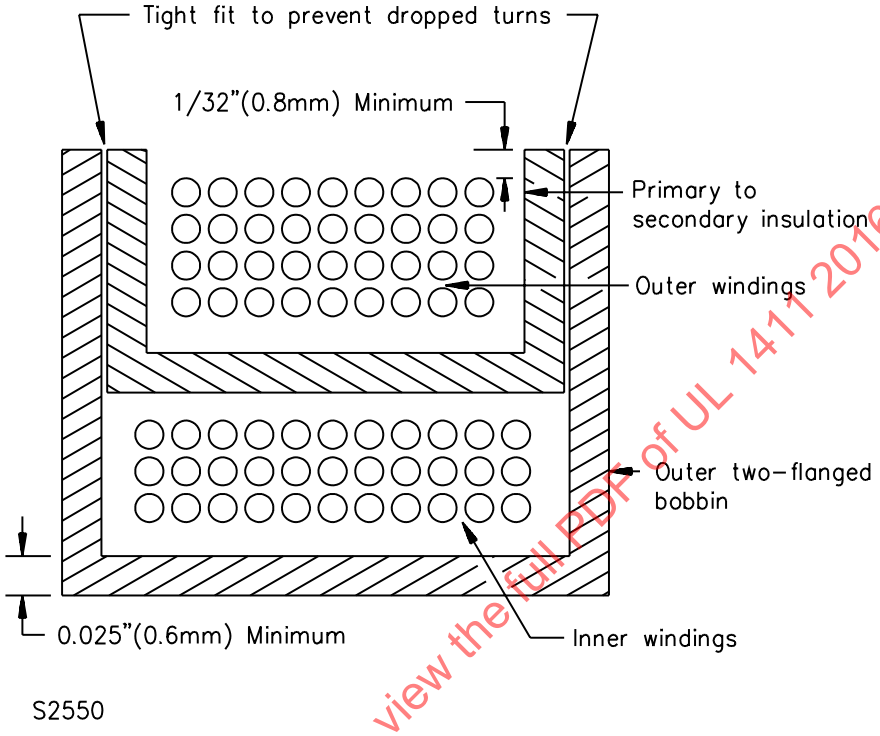


Figure 16.2
Bobbin wound transformer with 1/8 inch overlapped insulation on bobbin edges

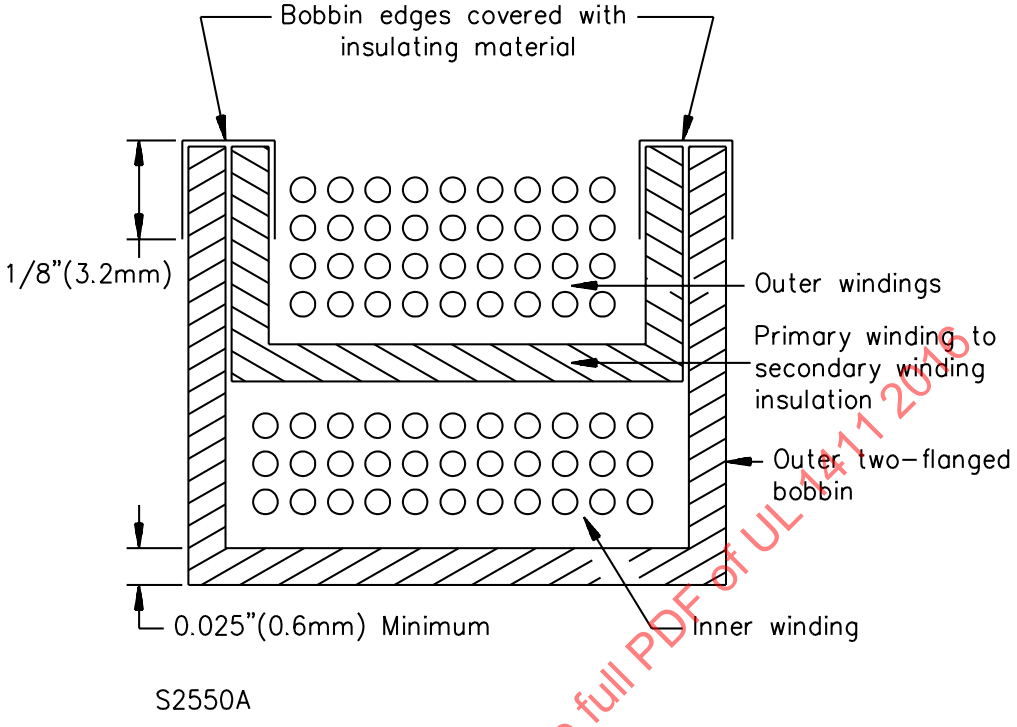
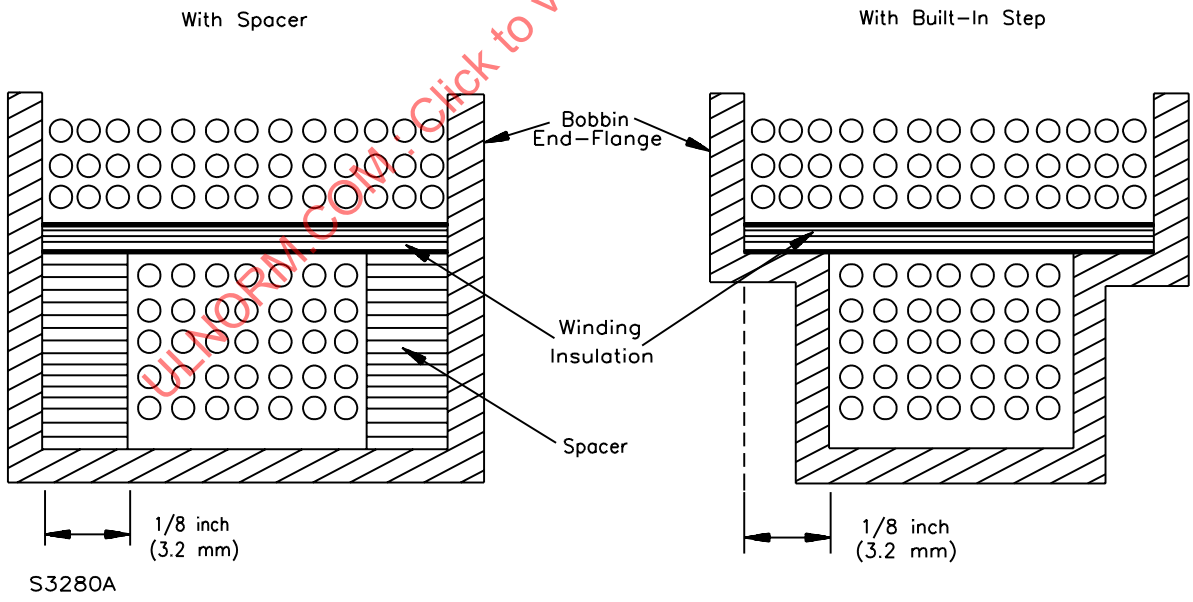


Figure 16.3
Bobbin wound transformer with offset coils



NOTE: The 1/8 inch (3.2 mm) spacing may be reduced to 1/16 inch (1.6 mm) as specified in Exception Nos. 1 and 2 to 16.2(c).

Figure 16.4
Bobbin wound transformer with overlapped tape

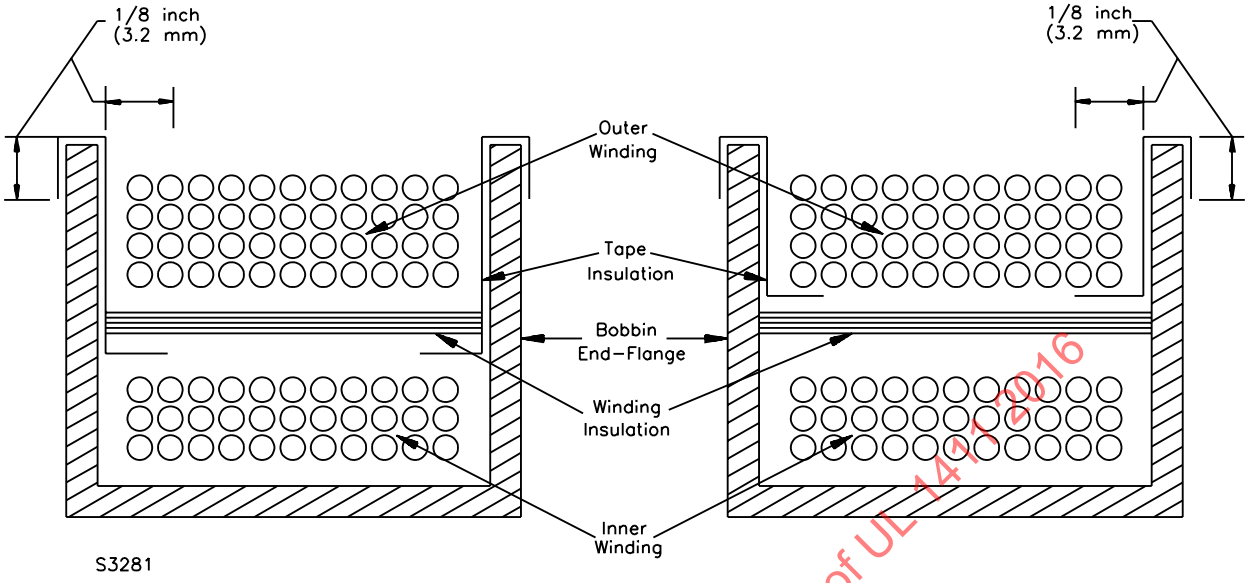
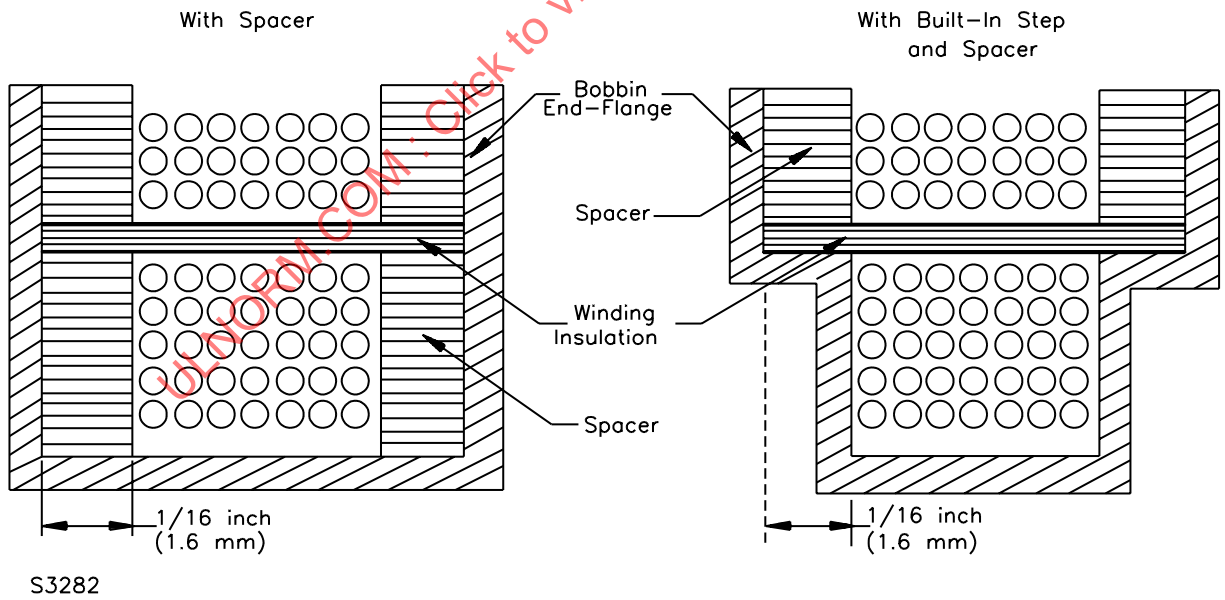


Figure 16.5
Bobbin wound transformer with inset coils



NOTE: The 1/16 inch (1.6 mm) spacing may be reduced to 1/32 inch (0.8 mm) as specified in Exception Nos. 1 and 2 to 16.2(e).

17 Double Protection

17.1 A transformer intended to comply with the requirements for double protection against a risk of electric shock in the Standard for Audio-Video Products and Accessories, UL 1492, shall comply with the requirements in 17.2 and 17.3. The requirements in 17.2 and 17.3 do not apply to a transformer intended for use in an end product where double protection is not required.

17.2 Insulated lead wires shall comply with the requirements in 7.1.1 and shall have insulation of either of the following constructions:

a) Two separate layers of insulation having a total thickness not less than 0.026 inch (0.66 mm), neither layer of which is less than 0.007 inch (0.18 mm) thick; or

b) A single layer of insulation not less than 0.027 inch (0.068 mm) thick.

17.3 Insulation providing double protection shall withstand a potential of 3500 volts, 60 hertz for 1 minute applied in accordance with the Dielectric Voltage-Withstand Test, Section 25. The dielectric voltage-withstand potential may also be required between the secondary winding and the core, depending on the end-use application. When a conductive connection is provided between the primary and secondary windings as described in Interconnection of Windings, Section 8, the primary lead and the body of the component is to be left in place, but the other lead is to be physically removed.

18 Transformers for Use with Hospital-Appliance Pendant Controls

18.1 In addition to the other applicable requirements in this standard, a transformer intended for connection to a pendant control of a hospital television receiver in accordance with the Standard for Audio-Video Products and Accessories, UL 1492, shall be constructed to provide physical separation between the primary and secondary windings so that the winding potential cannot be impressed on the secondary winding. See 18.2.

18.2 The physical separation described in 18.1 shall be accomplished by any one of the following manners:

a) The primary and secondary windings shall be insulated from and wound on separate legs of the core of the transformer.

b) Primary and secondary windings shall be wound concentrically. A grounded-copper shield at least 0.005 inch (0.13 mm) thick, or the equivalent, shall be provided between the primary and secondary windings and grounded to the core either directly or by a conductor. The conductor between the shield and the core shall be at least equal in size to the primary leads but not smaller than 24 AWG (0.21 mm^2). The shield shall completely separate the primary and secondary windings, including all splices and crossover leads, when provided. The shield shall extend the full width of the coil windings.

c) The primary and secondary windings shall be wound end-to-end, not concentric, on the same leg of the core, and the two windings shall be separated by a 1/32-inch (0.8-mm) thick barrier of phenolic or melamine or a barrier having equivalent characteristics.

d) The primary and secondary windings shall be wound concentrically, and the windings, including splices and crossover leads, shall be insulated by mica, not less than 0.007 inch (0.18 mm) thick, or another insulating material having equivalent resistance to ignition characteristics.

e) Other constructions equivalent to those described in (a) – (d).

PERFORMANCE

19 General

19.1 To determine which performance tests are required for the appliance in which the transformer is to be used, transformers are separated into two categories depending on secondary voltage and output power as follows:

a) Transformers having a secondary winding or windings operating at 42.4 volts peak – maximum voltage for all secondary windings – or less and having a winding impedance that limits the total output power from all windings to 15 watts or less.

b) Transformers having a secondary winding or windings operating at more than 42.4 volts peak – maximum voltage from all secondary windings – or having a total output power from all windings exceeding 15 watts. This includes all autotransformers.

19.2 A transformer shall be subjected to the applicable tests described in Sections 19 – 29.

Exception: The tests described in Sections 20, 21, and 29 need not be conducted if the manufacturer so requests. See 19.3.

19.3 When the tests described in Sections 20, 21, and 29 are not conducted on a transformer, they are to be considered during the investigation of the complete appliance. The appliance standard may require that the tests described in Abnormal Operation Tests, Section 29, be conducted on a transformer having output limitations as mentioned in 19.1(a).

19.4 All operational tests are to be conducted with the transformer connected to a supply circuit of rated frequency and the voltage specified in Table 19.1. When the unit is rated for a range of frequencies, such as 50 – 60 hertz, or is rated for dual frequencies, such as 50/60 hertz, tests are to be conducted at 60 hertz except as indicated in 20.2 and 21.2.

Table 19.1
Operational test voltages

Test	Sections	Voltage rating	Test voltage
Normal operation	20 – 22	105 – 130	Maximum rated voltage but not less than 120[a]
Normal operation	20 – 22	210 – 250	Maximum rated voltage but not less than 240
Abnormal operation	23, 24, 29	105 – 130	130[a]
Abnormal operation	23, 24, 29	210 – 250	b

[a] Transformer taps rated 100 volts may be tested if the manufacturer so requests. The test voltage is to be 100 volts for normal operation and 110 volts for abnormal operation.

[b] The test voltage is to be 110 percent of rated voltage but not less than 240 volts nor more than 260 volts.

20 Power Input Test

20.1 The power input of a transformer is to be measured when the transformer is operated with the secondary winding or windings delivering the rated output power or current specified by the manufacturer.

20.2 The transformer is to be connected to its rated source of supply. When a product is rated for dual frequencies or a range of frequencies, as indicated in 19.4, the test is to be conducted at the lowest frequency rating. A variable external resistor is to be connected across the secondary winding or windings and adjusted to consume rated output power or current as measured with a wattmeter or ammeter. The rotor of a motor-transformer is to be free running – no load – during this test. The output power or current rating is to be that assigned by the manufacturer.

21 Temperature Test

21.1 When a transformer is delivering its rated output, the maximum temperature rises at specified points shall not be greater than the applicable values specified in Table 21.1.

Table 21.1
Maximum temperature rises

Material	Degrees °C	Degrees (°F)
1. Varnished-cloth insulation	60	(108)
2. Fiber employed as electrical insulation	65	(117)
3. Rubber- or thermoplastic-insulated wire or coil	35	(63)
4. Class 105 insulation systems on windings		
Thermocouple method	65	(117)
Resistance method	75	(135)
5. Class 130 insulation systems on windings[a]		
Thermocouple method	85	(153)
Resistance method	95	(171)
6. Class 155 insulation systems on windings[a]		
Thermocouple method	110	(198)
Resistance method	115	(207)
7. Class 180 insulation systems on windings[a]		
Thermocouple method	125	(225)
Resistance method	135	(243)
8. Coil form		
Nylon	40	(72)
Other thermoplastic	25	(45)
9. Laminated phenolic composition	100	(180)
10. Phenolic composition	125	(225)
11. Sealing compound	b	b

NOTE – These limitations do not apply to an insulated conductor or a material that has been investigated and found to be acceptable for a higher temperature. A thermoplastic coil form is to be investigated to determine the effects of aging and pressure exerted by the windings.

[a] These limitations apply to an insulation system investigated in accordance with the Standard for Systems of Insulating Materials – General, UL 1446, and determined to be acceptable for the temperature class indicated.

[b] The maximum sealing compound temperature when corrected to a 25°C (77°F) ambient temperature, is 15°C (27°F) less than the softening point of the compound determined in accordance with the Standard Test Methods for Softening Point by Ring-and-Bell Apparatus, ASTM E28.

21.2 The transformer is to be mounted on a softwood surface in a draft-free area, and operated until constant temperatures are reached while operating as described in 20.1. When a product is rated for dual frequencies or a range of frequencies, as indicated in 19.4, the test is to be conducted at the lowest frequency rating.

21.3 All temperature rise values specified in Table 21.1 are based on an assumed ambient temperature of 25°C (77°F). Tests may be conducted at any ambient temperature within the range of 20 – 30°C (68 – 86°F).

21.4 When using the resistance method, the windings are to be at room temperature at the start of the test. The temperature rise of a winding is to be calculated from the formula:

$$\Delta t = \frac{R}{r}(k + t_1) - (k + t_2)$$

in which:

Δt is the temperature rise in °C;

R is resistance of the coil at the end of the test in ohms;

r is resistance of the coil at the beginning of the test in ohms;

k is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum. Values of the constant k for other grades must be determined;

t_1 is room temperature at the beginning of the test in °C; and

t_2 is room temperature at the end of the test in °C.

22 Open-Circuit Voltage Test

22.1 The maximum secondary open-circuit voltage between any two terminals or combination of terminals of a transformer shall be determined.

22.2 When measuring the total secondary voltages, the secondary winding or windings are to be connected such that the maximum voltage results.

23 Power Output Test

23.1 The total output power of the secondary winding or windings into an external resistor shall be determined.

23.2 For the purpose of calculating the total output power of the secondary winding or windings, the maximum power of each winding that can be delivered into the external resistor is to be measured with the other secondary winding or windings loaded to rated current or power. The power from each winding is to be added to the others for a total.

23.3 Any external protective device is to be defeated for the purpose of categorizing the transformer in accordance with 19.1(a).

24 Stalled Rotor Test

24.1 Stalling the rotor of a motor-transformer shall not result in a risk of fire or electric shock.

24.2 Three samples are to be subjected to the stalled-rotor test for 7 hours. During the test, the secondary winding or windings are to deliver rated output power or current and the test conditions are to be as described in 29.1.7.

25 Dielectric Voltage-Withstand Test

25.1 General

25.1.1 A transformer shall withstand for 1 minute the application of a 2875 volt, 40 – 70 hertz essentially sinusoidal potential without an indication of unacceptable performance. For a definition of unacceptable performance, see 25.1.6. The potential is to be applied:

a) Between any live part of the primary circuit and any dead metal part; and

b) Between any live part of the primary circuit and any live or current-carrying part of the secondary circuit.

Exception: This requirement does not apply to a transformer that is intended for use in an appliance where the transformer core and secondary windings are electrically isolated by acceptable means from all accessible metal parts.

25.1.2 Except when being tested after the thermoplastic bobbin temperature stability and abnormal tests (see 26.1 and 29.1.9), the transformer is to be at room temperature during the Dielectric Voltage-Withstand Test.

25.1.3 When conducting the Dielectric Voltage-Withstand Test, the applied 40 – 70 hertz voltage is to be measured directly across the application points of the test potential with a voltmeter having a minimum input impedance of 2 megohms (or by an equivalent means).

25.1.4 When applying the test voltage to the product or circuit, transient voltages shall not cause the instantaneous voltage to exceed 105 percent of the peak value of the specified test voltage. The applied potential is to be:

a) Increased from zero at a uniform rate that reaches the specified test potential in approximately 5 seconds; and

b) Maintained at the test potential for 1 minute.

Manual or automatic control of the rate of rise may be used.

25.1.5 The test equipment for conducting an AC Dielectric Voltage-Withstand Test is to have an output voltage that has:

a) A sinusoidal waveform;

b) A frequency within 40 – 70 hertz; and

c) A peak value of the waveform that is not less than 1.3 and not more than 1.5 times the rms value.

25.1.6 The sensitivity of the test equipment is to be adjusted so when a 120,000-ohm resistor is connected across the output, the equipment indicates a dielectric breakdown for any output voltage equal to or greater than the specified test voltage. However, it should not indicate a breakdown for any output voltage less than the specified test voltage. The calibrating resistor is to be adjusted as close to 120,000 ohms as accurately possible, but not more than 120,000 ohms.

Exception: The sensitivity of the test equipment may be increased (a higher value of calibrating resistance used) when agreeable to those concerned.

25.2 Insulation comparison

25.2.1 Regarding 13.3(c), an insulating material other than those materials specified in Equivalent Generic Materials, Section 15, shall withstand, without electrical breakdown, the applicable voltage specified in Table 25.1 when tested in accordance with 25.2.2 – 25.2.6.

Table 25.1
Insulation-comparison test voltages

Required thickness for electrical grade paper		Test voltage
inch	(mm)	
0.0035	(0.09)	1050
0.007	(0.18)	1700
0.012	(0.30)	2500
0.015	(0.38)	2900
0.023	(0.58)	4000

25.2.2 Rupture or decomposition of the material is considered to be evidence of breakdown.

25.2.3 The test specimen is to represent the material used in the transformer. More than one material or more than one layer of material, or both, may be used.

25.2.4 The test specimen shall be sized so that electrical discharge does not occur around the edges of the specimen.

25.2.5 The test specimen is to be placed between two opposing electrodes. The electrodes are to be cylindrical brass or stainless steel rods 1/4 inch (6.40 mm) in diameter with edges rounded to a 1/32-inch (0.8-mm) radius. The upper moveable electrode is to weigh 50 ±2 grams to exert sufficient pressure on the specimen to provide good electrical contact.

25.2.6 The applied test potential is to be increased at a uniform rate of approximately 500 volts per second from zero to the applicable value specified in Table 25.1 and held at that value for 1 minute. The potential is to be essentially sinusoidal and have a frequency within 40 – 70 hertz.

25.3 Induced potential

25.3.1 As specified in Exception No. 3 to 13.10, when necessary, a transformer shall be subjected to an operating potential, applied between the terminals of one winding, of twice the rated voltage of the winding with the ends of all other windings of the transformer open. The potential may be at any applicable frequency and shall be applied for 7200 cycles. The results are acceptable when there is no dielectric breakdown.

Exception: At any frequency less than 120 hertz, the potential is not to be applied for more than 60 seconds.

25.3.2 The test voltage specified in 25.3.1 is to be started at one-quarter or less of the full value and gradually increased to the full value in not more than 15 seconds. After being held for the time specified, the voltage, within 5 seconds, is to be slowly reduced to one-quarter of the maximum value or less, and the circuit is to be opened.

25.4 Production-line dielectric potential suitability test

25.4.1 When a manufacturer conducts the production-line dielectric voltage-withstand test at a potential or duration, or both, greater than that shown in Curve A of Figure 30.1, three samples of each representative transformer construction shall be subjected to the continuous application of the potential that the manufacturer intends to use for a duration that is 100 times the factory-test time. There shall be no indication of dielectric breakdown as a result of this test.

26 Thermoplastic Bobbin Temperature Stability Test

26.1 Each of three samples of a transformer employing a thermoplastic bobbin shall be subjected to a dielectric voltage-withstand test of 900 volts AC for 1 minute, conducted as described in 25.1.1 following 7 hours of conditioning in an air-circulating oven. The oven temperature shall be 10°C (18°F) higher than the maximum operating temperature specified by the manufacturer, but not less than 90°C (194°F).

27 Strain Relief Test

27.1 The strain-relief means on each insulated lead shall withstand a force equal to the weight of the transformer, but not less than 3 pounds (13.4 N) nor more than 10 pounds (45 N). The force is to be applied to the lead for 1 minute in any direction permitted by the construction with the parts and strain-relief means at room temperature. The lead shall not pull out of the transformer or be displaced to the extent that strain is transmitted to the internal connections.

28 Insulation Resistance Test

28.1 Immediately after exposure for 24 hours to moist air having a relative humidity of 85 ±5 percent at a temperature of 32.0 ±2.0°C (89.6 ±3.6°F), a transformer shall have an insulation resistance of not less than 10 megohms:

a) Between any live part of the primary and any dead metal part; and

b) Between any live part of the primary and any live or current-carrying part of the secondary circuit.

Exception: This requirement does not apply to a transformer that is intended for use in an appliance where the transformer core and secondary windings are electrically isolated by acceptable means from all accessible metal parts.

28.2 One sample is to be subjected to the insulation-resistance measurement. The measurement is to be made with an instrument having a direct-current open-circuit output voltage of 500 volts. When a conductive connection is provided between the primary and secondary windings, as described in Interconnection of Windings, Section 8, the primary lead and body of the component are to be left in place but the other lead is to be physically removed.

29 Abnormal Operation Tests

29.1 General

29.1.1 Transformer samples that are subjected to either the 7-hour or 15-day abnormal operation tests described in this section:

a) Shall not cause the adjacent cheesecloth or tissue paper to glow or flame;

b) Shall not have a dielectric breakdown when the dielectric voltage-withstand test described in 29.1.9 is conducted;

c) For the 15-day test, shall not cause the 1 ampere fuse connected to earth ground to open; and

d) For the 7-hour test, shall have a primary winding temperature rise, as determined by the change of resistance method, that does not exceed the maximum temperature rise specified in Table 29.1.

Table 29.1
Maximum temperature rise under abnormal conditions

Temperature index of insulation	Maximum temperature rise[a]	
	°C	(°F)
105	105	(189)
130	135	(243)
155	160	(288)
180	185	(333)
200	225	(405)
220	255	(459)

NOTE – Based on an assumed ambient temperature of 25°C (77°F). Tests are to be conducted at any ambient temperature within the range of 20 – 30°C (68 – 86°F).

[a] The maximum temperature rise under abnormal conditions for other index ratings of insulation is 30°C (54°F) higher than the normal temperature rise limit. See 29.2.2 and 29.2.3.

29.1.2 For the purposes of these requirements, each secondary winding tap, other than a center tap, and each primary-winding tap intended to supply power to a load are considered to be a secondary winding. When a transformer has more than one secondary winding, each of the secondary windings is to be individually tested.

29.1.3 Samples of the transformer are to be subjected to secondary winding loading conditions in this test sequence:

a) Short-circuit;

b) Rated current plus 75 percent of the difference between the short-circuit current and the rated current;

c) Rated current plus 50 percent of the difference between the short-circuit current and the rated current;

d) Rated current plus 25 percent of the difference between the short-circuit current and the rated current;

e) Rated current plus 20 percent of the difference between the short-circuit current and the rated current;

f) Rated current plus 15 percent of the difference between the short-circuit current and the rated current;

g) Rated current plus 10 percent of the difference between the short-circuit current and the rated current;

h) Rated current plus 5 percent of the difference between the short-circuit current and the rated current; and

i) Rated current.

29.1.4 To determine the short-circuit current for the tests described in 29.1.3 (b) – (h), the transformer is to be at room temperature at the beginning of the measurement, and the short-circuit current is to be measured approximately 1 minute after the application of voltage to the primary winding. An external protective device, if provided by the manufacturer, is to be short-circuited during this measurement. If the 30-ampere line fuse or transformer winding opens within 1 minute after the application of the primary voltage, the short-circuit current is considered to be the current recorded just before the line fuse or winding opens. The short-circuit current of any one winding is to be measured with the other secondary windings open-circuited.

29.1.5 A transformer shall operate continuously under 29.1.3(i) for the full test period – 7 hours or 15 days, as applicable.

29.1.6 For the loading conditions of 29.1.3 (b) – (i), a variable resistor is to be adjusted to result in the required value of winding current as quickly as possible and readjusted, if necessary, 1 minute after application of voltage to the primary winding.

29.1.7 Samples for the abnormal operation tests are to be prepared as follows:

a) The transformer is to be placed on a white-tissue-paper-covered softwood surface.

b) For a 15-day test, exposed dead metal parts and one end of each secondary winding are to be connected to earth ground through a 1-ampere nontime-delay fuse.

Exception: The fuse need not be employed if its connection would create a condition that is not likely under single-fault conditions (for example, a transformer used in an appliance where the transformer core and secondary windings are electrically isolated from all accessible metal parts by a means determined acceptable).

c) A single layer of cheesecloth is to be draped loosely over the transformer or its individual enclosure.

d) All primary and secondary protective devices specified by the manufacturer are to be connected in the circuit.